Deerfield River Flow Monitoring Study

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Executive Summary

Introduction:

This study's objective was to establish manual water level staff gages below the Fife Brook Hydroelectric Project (Project) on the mainstem Deerfield River, as well as install data logging equipment to collect continuous data from a previously installed water level sensor. The overall study goal was to provide a means to monitor streamflow below the Project in an effort to assure all river users, the project owners, and regulatory agencies that prescribed minimum and other regulatory flows are being maintained.

Manual Staff Gage Installation

At the location of a discontinued USGS gage (Deerfield River at Rowe, MA, Gage No. 01168151), below the Fife Brook Hydroelectric Project, a series of manual staff gages capable of measuring gage heights (streamflows) ranging from 1.60 feet (17.6 cubic feet per second [cfs]) to 8.42 feet (4,299 cfs) were installed. The manual staff gages will serve the following functions:

- An independent reference gage to indicate the water level or stage height in the river;
- When necessary, gage readings taken on the manual staff gage should be used to recalibrate the water level sensor; and
- A temporary substitute for the water level sensor if there is an equipment failure. The manual staff gages can be read as needed by local observers to continue the record of gage height during the malfunction.

Stage-Discharge Rating Curve Development

Continuous records of streamflow are computed by applying a stage-discharge rating curve developed for the site to measurements of stage height. Stage-discharge rating curves for gaging stations are usually determined by plotting measurements of streamflow (discharge) and gage height (stage). For this study, several stream discharge measurements were made to define a stage-discharge rating curve for this site. In terms of the prescribed minimum flow at the Fife Brook Hydroelectric Project, a gage height of 2.89 feet or greater is needed to meet or exceed the 125 cfs requirement.

Collection of Continuous Streamflow Data

An electronic datalogger was installed in conjunction with a pre-existing water level sensor, owned by USGen New England Inc. (USGen), to record gage heights at the site. This datalogger was programmed to convert the measured gage heights to streamflow using the stage-discharge relationship, and then store these readings in its memory. The water level sensing and data logging equipment are sheltered in a discontinued USGS gage house.

Volunteers were trained on the steps necessary to accurately read the manual staff gages installed at the site, as well as properly download gage height and streamflow information from the data logger. An MS Access database was developed to store the gage height readings collected by volunteers. The database is designed to automatically convert the gage heights to streamflow using the stage-discharge relationship, as well as calculate a series of statistics.

Recommendations

The following are recommendations to assist river users in continued monitoring of streamflow on the Deerfield River.

- It is recommended that the Deerfield River near West Deerfield, MA (Gage No. 01170000) USGS gage be used to monitor flows from the Station No. 2 project. This gage can be used to give a close approximation of the timing and magnitude of flow releases from Station No. 2. It was agreed that in lieu of installing a second manual staff gage at Bardwell Ferry, the resources allocated for this item were used to facilitate continuous streamflow monitoring below the Fife Brook Hydroelectric Project. The main purpose of the proposed Bardwell Ferry manual staff gage was to monitor flow releases from the Station No. 2 project, as the stream reach below the project is a high quality coldwater fishery. Bardwell Ferry and the Deerfield River near West Deerfield, MA (Gage No. 01170000) USGS gage are located approximately 2.5 miles and 4.4 miles below the Station No. 2 project, respectively.

  The drainage area at Station No. 2 is 505 square miles, while the drainage area at the USGS gage is 557 square miles. Thus, 52 square miles of unregulated drainage area contributes flow to this stream reach, in addition to the flow releases from Station No. 2.

  For a closer approximation of project flow releases, flow from the South River can be subtracted from the total flow measured at the Deerfield River near West Deerfield, MA USGS gage. Flow from the South River USGS gage, which enters the Deerfield River 0.4 miles upstream of the West Deerfield USGS gage, is measured by the South River near Conway, MA (Gage No. 01169900) USGS gage (see Figure 1). The drainage area measured by the South River USGS gage is approximately 24 square miles; thus the flow resulting from subtracting South River flow from flow measured at the West Deerfield USGS gage would reflect 28 square miles of unregulated drainage area between the project and the West Deerfield USGS gage.

- It is recommended that an annual survey of the gage reference marks, as well as the manual staff gage and water level sensor elevations be conducted so that any movement, settling, etc. can be noted and corrected. All reference marks and gage elevations are surveyed in at 0.01 feet accuracy. Streamflow measured at the Fife Brook Hydroelectric Project gage can become inaccurate if correct station survey levels are not maintained.

- It is recommended that streamflow measurements be conducted on an annual basis to either verify the accuracy of the stage-discharge rating curve or to follow changes (shifts) in the rating. Substantial sediment deposition or erosion near the area of a gage location can cause a shift in a stage-discharge rating curve. Shifts in the discharge rating reflect the fact that stage-discharge rating curves are not always permanent but vary from time to time, either gradually or abruptly. According to the USGS, if a streamflow measurement is within 5 percent of the streamflow discharge value indicated by the stage-discharge rating curve, the measurement is considered to verify the rating curve. However, if several consecutive measurements meet the 5-percent criterion, but they all plot on the same side of the defined segment of the stage-discharge rating curve, they may be considered to define a period of shifting control.

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1 Introduction

This study was requested by the Deerfield River Watershed Team and funded by the Executive Office of Environmental Affairs (EOEA) under the Massachusetts Watershed Initiative. The study contract management and technical oversight was provided by the Massachusetts Department of Conservation and Recreation (MDCR) [formerly the Massachusetts Department of Environmental Management, Office of Water Resources]. This study's objective was to establish manual water level staff gages below the Fife Brook Hydroelectric Project (Project) on the mainstem Deerfield River, as well as install data logging equipment to facilitate the collection of continuous streamflow data below the Project. The overall study goal was to provide a means to monitor streamflow below the Project in an effort to assure all river users, the project owners, and regulatory agencies that prescribed minimum and other regulatory flows are being maintained.

Originally, the project scope outlined plans to establish up to two manual staff gages; one below the Fife Brook Hydroelectric Project and another potentially at Bardwell Ferry below the Station No. 2 Project. The gages were to be manually read by volunteers on an intermittent basis. These stream reaches provide high-quality coldwater fishing opportunities. The reach below the Fife Brook Hydroelectric Project is well known for its whitewater recreational boating opportunities as well.

During the May 7, 2003 Deerfield River watershed team meeting, several members expressed a desire for continuous flow monitoring below the Fife Brook Hydroelectric Project; as opposed to a manual staff gage only. Coincident to this study, USGen New England, Inc. (USGen) was in the process of installing a water level sensor within the United States Geological Survey (USGS) gage house[1] located approximately 600 feet below the Fife Brook Hydroelectric Project. The purpose of the sensor was to make continuous water level readings in this river reach and to alert USGen operations personnel if the streamflow level fell below the regulatory standard.

After further conversations with USGen, and the Millers/Deerfield River and Taconic Chapters of Trout Unlimited, it was agreed that in lieu of installing the second manual staff gage at Bardwell Ferry, the resources originally allocated for that item would be applied to the purchase of digital data logging equipment. MDCR processed a contract amendment to reflect these changes in the original scope of services. The data logging equipment was installed in conjunction with the water level sensor to store the readings digitally and thereby provide a continuous record of streamflow levels below the Project. Volunteers were trained on procedures to download the water level data and read the manual staff gages, convert the water level data to streamflow values, and properly maintain the equipment.

This report describes the installation and monitoring procedures for the manual staff gages, the development of a stage-discharge rating curve to be used in converting water level data to streamflow values, and download procedures related to the digital data logger. Several recommendations are provided as well.

2 Description of Project Area

The Deerfield River is located in northwestern Massachusetts and southern Vermont and drains an area of approximately 665 square miles. The Deerfield River is one of the principal tributaries of the Connecticut

[1] The Deerfield River at Rowe, MA (Gage No. 01168151) streamflow gage was operated by the USGS from 5/24/1974 to 9/30/1997. After data collection was discontinued in 1997, the USGS removed the outside manual staff gages and continuous data recording equipment within the gage house. The gage house remained intact.

River. On the mainstem of the Deerfield River there are three Federal Energy Regulatory Commission (FERC) licensed hydroelectric power projects. The 76.9-megawatt (MW) Deerfield River Hydroelectric Project (FERC No. 2323) is owned by USGen, and is comprised of seven generating facilities on the mainstem of the Deerfield River and a seasonal storage facility on the East Branch of the Deerfield River (see Table 1). The Bear Swamp Pumped Storage Project (FERC No. 2669), also owned by USGen, is comprised of the 600 MW Bear Swamp pump/generating facility and the 11.3 MW Fife Brook Hydroelectric Project. The Fife Brook development is located on the mainstem of the Deerfield just downstream of Station No. 5 (part of the Deerfield River Hydroelectric Project) and forms the lower reservoir for the Bear Swamp pump/generating facility. The 3.6 MW Gardners Falls Hydroelectric Project (FERC NO. 2334) is owned by Consolidated Edison (ConEd) and is located on the mainstem of the Deerfield River between Station Nos. 3 and 2 (each of which are part of the Deerfield River Hydroelectric Project).

Table 1: Hydroelectric Facilities Located on the Deerfield River

Station Name	River Mile (RM)	State	Capacity (MW)	Drainage Area (sq mi)
Somerset	66.0	VT	0 (storage only)	30
Searsburg	60.3	VT	4.2	90
Harriman	48.5	VT	33.6	184
Sherman	42.0	VT / MA	7.2	234
Station No. 5	41.2	MA	17.6	237
Bear Swamp	39.0	MA	600	254
Fife Brook	37.0	MA	11.3	254
Station No. 4	20.0	MA	4.8	404
Station No. 3	17.0	MA	4.8	500
Gardners Falls	15.7	MA	3.6	502
Station No. 2	13.2	MA	4.8	505

A FERC license, containing several operating and regulatory conditions, was issued in 1997 for Deerfield River Hydroelectric Project (FERC No. 2323). Among the conditions are requirements to pass continuous minimum flows at all of the hydroelectric projects. These minimum flows were determined through studies and negotiations with stakeholders during the hydroelectric facility's relicensing process, and were established to protect aquatic resources in the Deerfield River.

The Massachusetts Department of Environmental Protection (MDEP) maintains regulatory oversight at the Station No. 5, Station No. 4, Station No. 3, Station No. 2, Gardners Falls, and Fife Brook Hydroelectric Projects (see Figure 1). During the FERC relicensing process, the following minimum flow schedules were developed for these Projects.

Table 2: Minimum Flows at Deerfield River Hydroelectric Facilities Located within Massachusetts

Time Period	Project	Minimum Flow (cfs)
All Year	Station No. 5	73
All Year	Fife Brook	125
October 1-May 31 June 1-September 30	Station No. 4	100 125
All Year	Station No. 3	100
All Year	Gardners Falls	150
All Year	Station No. 2	200

As shown in Figure 1, there are currently two active USGS gages located on the mainstem of the Deerfield River. They are the Deerfield River at Charlemont, MA (Gage No. 01168500) and the Deerfield River near West Deerfield, MA (Gage No. 01170000). In addition, the Deerfield River at Rowe, MA (Gage No. 01168151), located just below the Fife Brook Hydroelectric Project, was operational until September 30, 1997 before it was discontinued. Several tributaries to the mainstem Deerfield River are also gaged as well. They include the South River near Conway, MA (Gage No. 01169900), the North River at Shattuckville, MA (Gage No. 01169000), and the Green River near Colrain, MA (Gage No. 01170100). Pertinent information for each USGS gage is shown in Table 3.

Table 3: USGS Gages in the Deerfield River Watershed within Massachusetts

Gage	Gage No.	Drainage Area (square miles)	Period of Operation
Deerfield River at Rowe, MA	01168151	254	1974-1997
Deerfield River at Charlemont, MA	01168500	361	1913-Present
North River at Shattuckville, MA	01169000	89.0	1939-Present
South River near Conway, MA	01169900	24.1	1967-Present
Green River near Colrain, MA	01170100	41.4	1966-Present
Deerfield River near West Deerfield, MA	01170000	557	1904-Present

3 Installation of Manual Staff Gages

A water surface elevation referenced to an arbitrary or predetermined datum is called the gage height. Gage height is often used interchangeably with the more general terms of stage and water level, although gage height is more appropriate when used with a reading on a gage. Stage or gage height is usually expressed in feet and hundredths (0.01 ft) of a foot.

In streamflow gaging, gage heights (i.e., stage) are used as the independent variable in the stage-discharge rating curve to derive streamflow discharges. Reliability of the streamflow discharge record is therefore dependent on the reliability of the gage height record as well as the stage-discharge rating curve.

For the purposes of this study, a continuous record (i.e., readings every 15 minutes) of gage height below the Fife Brook Hydroelectric Project will be determined using USGen's water level sensor. These gage heights will be stored digitally on a data logger installed in conjunction with the water level sensor.

The manual staff gages will serve several auxiliary functions to the water level sensor and data logger. They include the following:

- As an independent reference gage to indicate the gage height and in turn streamflow in the river;
- When necessary gage readings taken on the manual staff gage should be used to recalibrate the water level sensor; and
- As a temporary substitute for the water level sensor if there is an equipment failure. The manual staff gages can be read as needed by local observers to continue the record of gage height during the malfunction.

At the location of the discontinued USGS gage (Deerfield River at Rowe, MA, Gage No. 01168151), below the Fife Brook Hydroelectric Project, a series of manual staff gages were installed. The following is a description of the manual staff gage network installed as part of this study.

A standard USGS porcelain-enameled vertical staff gage was installed on a large boulder located near the left stream bank (see Figure 2). The vertical staff gage was affixed to a 2" by 6" pressure treated board, which was secured to the boulder using anchor bolts. The vertical staff gage covers a range of water levels from 1.60 feet to 5.00 feet, and is graduated over 0.02-foot intervals. The vertical staff gage was set to correspond to the reference marks (gage datum) used previously by the USGS at the site. It can be used to make observations of gage height during low to medium flow conditions. The vertical staff gage will also act as a reference gage for checking and recalibrating (if needed) the gage height indicated by USGen's water level sensor, which is enclosed in the existing gage house.

In addition, an inclined staff gage was installed on the left stream bank. The staff gage was constructed of 4" by 4" pressure treated timbers, and secured to the stream bank using anchor bolts (see Figure 3). The inclined staff gage covers a range of gage heights from 2.54 feet to 6.86 feet, and is graduated over 0.10-foot intervals. Stainless steel staples (at 0.10 foot increments) and metal numerals (at every whole foot increment) were used for the graduations. This staff gage will be used to observe gage heights for medium to high flow conditions. In addition to covering a higher range of gage heights, an inclined staff gage built flush with the stream bank is less likely to be damaged by floods, floating ice, or drift than are projecting vertical staff gages.

For observing gage height at extreme high flow conditions, a standard USGS porcelain-enameled vertical staff gage was located high on the left stream bank (see Figure 4). This vertical staff gage covers a range of water levels from 6.76 feet to 8.42 feet, and is graduated over 0.02-foot intervals.

As mentioned previously, all three manual staff gages were surveyed to correspond to the reference marks (see Table 4) used at USGS gage when it was originally in operation. The surveying was completed on July 30, 2003. In addition, the elevation of the water level sensor (see Table 4) was also referenced to this local gage datum set. The entire gage station setup is shown in Figure 5.

Table 4: Local Elevation of USGS Gage Reference Marks and Water Level Sensor

Reference Mark	Local Elevation (ft)
Bolt on Inside Gage House Wall (RM #1)	30.668
Bolt on Outside Gage House Wall (RM #2)	23.005
Bolt in Boulder Located on Left Stream Bank (RM #3)	5.758
Bolt in Boulder Located Instream, near Left Stream Bank (RM #4)	4.649
Water Level Sensor Orifice Tube	2.100

4 Stage-Discharge Rating Curve Development

Continuous records of streamflow at gaging stations are computed by applying the stage-discharge rating curve[2] developed for the site to measurements of gage height. Stage-discharge rating curves for gaging stations are usually determined empirically by means of periodic measurements of streamflow (discharge) and gage height (stage). The streamflow measurements are usually made with a current meter. Measured streamflow is then plotted against concurrent gage height on graph paper to define the stage-discharge rating curve.

Stream discharge measurements were made to define a stage-discharge rating curve for this site. Discharge measurements were taken at two different locations: approximately 50 feet upstream from the

[2] The terms "rating," "rating curve," "stage rating," and "stage-discharge relation" are synonymous to stage-discharge rating curve and are often used interchangeably.

gage house within a riffle area (see Figure 6) and approximately 300 feet downstream from the gage house within a riffle area (see Figure 7). As calibration flows increased in magnitude it was necessary to move the measurement location downstream slightly, where the stream channel widened. This made it possible to safely wade the measurement cross section at the higher flows.

Flow measurements followed standard USGS stream gaging procedures. These flow measurements were computed using the formula Q=VA where;

Q= Streamflow (cfs),
V= average velocity (ft/sec), and
A= area (ft).

Prior to flow metering a tape measure was placed across the river channel. Starting on the right bank, a Marsh-McBirney Flow-Mate 2000 velocity meter was placed in the water, and pertinent data were recorded at 2.0-4.0 foot increments (cells) across the stream channel. The data collected for each cell consisted of mean column velocity (measured to the nearest 0.01 ft/sec), depth (measured to the nearest 0.05 foot) and width (measured to the nearest 0.1 foot). These data were used to compute the flow in each cell using the formula above. The flow within each cell was then summed to yield the total river flow.

Shown in Table 5 are the results of the calibration streamflow measurements and the corresponding gage height recorded from the manual staff gages. USGen controlled flow releases below the Project to allow for a range of flows to be measured. Figure 8 is a graphical depiction of the stage-discharge relationship. The streamflow measurement notes are presented in Appendix A.

Table 5: Results of Stage-Discharge Rating Curve Calibration Measurements

Measurement Date	Gage Height (ft)	Calibration Flow (cfs)
7/30/03	2.84	113
11/19/03	3.53	262
11/19/03	4.27	439
11/19/03	4.68	615
11/19/03	5.42	987

In practice, stage-discharge ratings curves are often extended or extrapolated beyond the range of discharge measurements. Shown in Table 6, is the expanded stage-discharge rating table (curve) for the site for gage heights ranging from 1.60 feet (17. 6 cfs) to 8.42 feet (4,299 cfs). However, it is possible that the extrapolated portion of the stage-discharge rating curve may not be as accurate, as that portion encompassed by the calibration flow measurements.

To utilize the rating curve, scroll down the column labeled gage height (ft) to match the observed gage height to the nearest 0.1 of a foot. Then scroll across the row to match the observed gage height to the nearest 0.01 of a foot. For example, a gage height of 3.06 feet would correspond to a flow of 150 cfs. In terms of the prescribed minimum flow at the Fife Brook Hydroelectric Project, a gage height of 2.89 feet or greater is needed to meet or exceed the 125 cfs requirement.

Table 6: Stage-Discharge Rating Table

	Discharge (cfs)									
Gage Height (ft)	**0.00**	**0.01**	**0.02**	**0.03**	**0.04**	**0.05**	**0.06**	**0.07**	**0.08**	**0.09**
1.6	17.6	17.9	18.3	18.7	19.1	19.4	19.8	20.2	20.6	21.0
1.7	21.5	21.9	22.3	22.7	23.2	23.6	24.1	24.5	25.0	25.5
1.8	25.9	26.4	26.9	27.4	27.9	28.4	28.9	29.4	30.0	30.5
1.9	31.0	31.6	32.1	32.7	33.2	33.8	34.4	35.0	35.6	36.2
2.0	36.8	37.4	38.0	38.6	39.3	39.9	40.6	41.2	41.9	42.5
2.1	43.2	43.9	44.6	45.3	46.0	46.7	47.4	48.2	48.9	49.7
2.2	50.4	51.2	52.0	52.7	53.5	54.3	55.1	55.9	56.8	57.6
2.3	58.4	59.3	60.1	61.0	61.9	62.7	63.6	64.5	65.4	66.3
2.4	67.3	68.2	69.1	70.1	71.1	72.0	73.0	74.0	75.0	76.0
2.5	77.0	78.0	79.1	80.1	81.2	82.2	83.3	84.4	85.5	86.6
2.6	87.7	88.8	89.9	91.1	92.2	93.4	94.6	95.8	96.9	98.1
2.7	99.4	101	102	103	104	106	107	108	109	111
2.8	112	113	115	116	117	119	120	122	123	125
2.9	126	127	129	130	132	133	135	136	138	139
3.0	141	142	144	146	147	149	150	152	154	155
3.1	157	159	160	162	164	166	167	169	171	173
3.2	174	176	178	180	182	184	186	187	189	191
3.3	193	195	197	199	201	203	205	207	209	211
3.4	213	215	217	220	222	224	226	228	230	233
3.5	235	237	239	241	244	246	248	251	253	255
3.6	258	260	262	265	267	270	272	275	277	280
3.7	282	285	287	290	292	295	298	300	303	306
3.8	308	311	314	316	319	322	325	327	330	333
3.9	336	339	342	345	347	350	353	356	359	362
4.0	365	368	371	374	378	381	384	387	390	393
4.1	396	400	403	406	409	413	416	419	423	426
4.2	429	433	436	440	443	447	450	454	457	461
4.3	464	468	471	475	479	482	486	490	493	497
4.4	501	505	508	512	516	520	524	528	532	536
4.5	540	544	548	552	556	560	564	568	572	576
4.6	580	585	589	593	597	601	606	610	614	619
4.7	623	628	632	636	641	645	650	654	659	664
4.8	668	673	677	682	687	692	696	701	706	711
4.9	715	720	725	730	735	740	745	750	755	760
5.0	765	770	775	780	785	791	796	801	806	812

	Discharge (cfs)									
Gage Height (ft)	**0.00**	**0.01**	**0.02**	**0.03**	**0.04**	**0.05**	**0.06**	**0.07**	**0.08**	**0.09**
5.1	817	822	827	833	838	844	849	855	860	866
5.2	871	877	882	888	893	899	905	911	916	922
5.3	928	934	939	945	951	957	963	969	975	981
5.4	987	993	999	1,005	1,011	1,018	1,024	1,030	1,036	1,043
5.5	1,049	1,055	1,062	1,068	1,074	1,081	1,087	1,094	1,100	1,107
5.6	1,113	1,120	1,127	1,133	1,140	1,147	1,153	1,160	1,167	1,174
5.7	1,181	1,188	1,194	1,201	1,208	1,215	1,222	1,229	1,236	1,244
5.8	1,251	1,258	1,265	1,272	1,279	1,287	1,294	1,301	1,309	1,316
5.9	1,324	1,331	1,338	1,346	1,353	1,361	1,369	1,376	1,384	1,392
6.0	1,399	1,407	1,415	1,423	1,430	1,438	1,446	1,454	1,462	1,470
6.1	1,478	1,486	1,494	1,502	1,510	1,519	1,527	1,535	1,543	1,552
6.2	1,560	1,568	1,577	1,585	1,593	1,602	1,610	1,619	1,627	1,636
6.3	1,645	1,653	1,662	1,671	1,680	1,688	1,697	1,706	1,715	1,724
6.4	1,733	1,742	1,751	1,760	1,769	1,778	1,787	1,796	1,806	1,815
6.5	1,824	1,833	1,843	1,852	1,862	1,871	1,880	1,890	1,900	1,909
6.6	1,919	1,928	1,938	1,948	1,958	1,967	1,977	1,987	1,997	2,007
6.7	2,017	2,027	2,037	2,047	2,057	2,067	2,077	2,087	2,098	2,108
6.8	2,118	2,128	2,139	2,149	2,160	2,170	2,181	2,191	2,202	2,212
6.9	2,223	2,234	2,245	2,255	2,266	2,277	2,288	2,299	2,310	2,321
7.0	2,332	2,343	2,354	2,365	2,376	2,387	2,398	2,410	2,421	2,432
7.1	2,444	2,455	2,467	2,478	2,490	2,501	2,513	2,525	2,536	2,548
7.2	2,560	2,571	2,583	2,595	2,607	2,619	2,631	2,643	2,655	2,667
7.3	2,679	2,691	2,704	2,716	2,728	2,741	2,753	2,765	2,778	2,790
7.4	2,803	2,815	2,828	2,841	2,853	2,866	2,879	2,892	2,904	2,917
7.5	2,930	2,943	2,956	2,969	2,982	2,995	3,009	3,022	3,035	3,048
7.6	3,062	3,075	3,088	3,102	3,115	3,129	3,142	3,156	3,170	3,183
7.7	3,197	3,211	3,225	3,239	3,253	3,266	3,280	3,294	3,309	3,323
7.8	3,337	3,351	3,365	3,379	3,394	3,408	3,423	3,437	3,451	3,466
7.9	3,481	3,495	3,510	3,525	3,539	3,554	3,569	3,584	3,599	3,614
8.0	3,629	3,644	3,659	3,674	3,689	3,704	3,720	3,735	3,750	3,766
8.1	3,781	3,797	3,812	3,828	3,843	3,859	3,875	3,890	3,906	3,922
8.2	3,938	3,954	3,970	3,986	4,002	4,018	4,034	4,050	4,067	4,083
8.3	4,099	4,116	4,132	4,149	4,165	4,182	4,198	4,215	4,232	4,248
8.4	4,265	4,282	4,299							

5 Overview of Water Level Sensor and Data Logger Setup

Coincident to this study, USGen was in the process of installing a water level sensor, manufactured by Sutron Corporation, within the USGS gage house located below the Fife Brook Hydroelectric Project. The water level sensor's purpose was to make continuous readings in the river reach below the Project and to alert USGen operations personnel by sending a signal, via a hardline cable, if the flow level fell below the regulatory standard. In general, the water level sensor (see Figure 9) measures the height of water above a fixed point (i.e., orifice tube end) in the stream. The measurements made by the water level sensor have been correlated to the gage datum used for the manual staff gages. General specifications for the water level sensor are included in Appendix B.

As part of this study, the CR510 Basic Datalogger, manufactured by Campbell Scientific, Inc. (www.campbellsci.com), was installed to record the gage heights measured by the water level sensor (see Figure 9). General specifications for the data logger are included in Appendix B as well. Auxiliary equipment from Campbell Scientific, Inc. necessary to complete this installation included the following:

- A 12" x 14" weather resistant enclosure to house the datalogger;
- A 2:1 voltage divider; and
- A RS-232 interface.

The water level sensor has the capability to relay its signal using a SDI (Serial Digital Interface)-12 or analog output. The CR510 is capable of reading both of these output types. A decision was made to connect the datalogger and the water level sensor using the analog output.

In general, the operation of the system is as follows. A reading of the water column height above the orifice tube end is made by the water level sensor. This reading is in the form of a voltage ranging from 0-5 volts, which is output from the sensor to the datalogger. The voltage range is calibrated to the water level measurement range programmed into the water level sensor. For the current configuration, the water level range was set at 0-15 feet. For instance, a reading of 5 volts would mean that the water column height above the orifice tube end is 15 feet. The datalogger was programmed to then convert the voltage reading to the appropriate gage height and in turn the appropriate streamflow using the stage-discharge relationship, and then store these readings in its memory.

The CR510 typically is constructed to read an analog output ranging between 0-2.5 volts; therefore it was necessary to also install a 2:1 voltage divider to increase this capacity to 0-5 volts. The RS-232 interface is used to facilitate communication between the datalogger and a computer for data download and datalogger programming.

Both the water level sensor and the datalogger operate on a 12-Volt battery, which is owned by USGen. A 110-Volt AC power line to the gage house, also owned by USGen, provides electrical power to a battery charger for the 12 Volt battery. The complete system is sheltered in the USGS gage house, which remains locked. USGen will be responsible for maintaining the water level sensor and power supply equipment (i.e., battery, charger, etc.).

6 Monitoring Protocol for Staff Gages and Data Download Procedures

The following sections describe the steps necessary to accurately read the manual staff gages installed at the site, as well as properly download gage height and streamflow information from the data logger.

6.1 Manual Staff Gages

The standard USGS porcelain-enameled vertical staff gage affixed to the large boulder (see Figure 2) can be used to record gage heights ranging from 1.60 feet (17.6 cfs) to 5.00 feet (765 cfs). This staff gage is graduated over 0.02-foot intervals, and therefore can be read to that precision with certainty. Readings to the 0.01-foot interval must be visually estimated. To make a gage height reading, simply read the graduation corresponding to the water line on the gage. For example the correct gage height reading for water level shown in Figure 2 would be 2.90 feet (126 cfs).

The inclined staff gage can be used to read gage heights from 2.54 feet (81.2 cfs) to 6.86 feet (2,181 cfs). This gage is graduated over 0.10-foot intervals and therefore can be read to that precision with certainty. Readings to the 0.01-foot interval must be visually estimated. Stainless steel staples (at 0.10-foot increments-see Figure 10) and metal numerals (at every whole foot increment-see Figure 10) were used for the graduations. To make a gage height reading on the inclined staff gage, simply read the graduation corresponding to the water line on the gage to the nearest 0.10-foot increment and estimate to the nearest 0.01-foot as necessary. For example the correct gage height reading for water levels (red lines) shown in Figure 10 would be 2.90 feet (126 cfs), 3.08 (154 cfs) feet, and 3.15 feet (166 cfs), respectively.

A second vertical staff gage is available high on the left stream bank for observing gage height at extreme high flow conditions (see Figure 3). This vertical staff gage covers a range of water levels from 6.76 feet (2,077 cfs) to 8.42 feet (4,299 cfs), and is read in exactly the same manner as the staff gage affixed to the large boulder.

A few important points to bear in mind when making gage height readings:

- Remove any floating debris from the gage, and gently scrub away any debris from the gage surface;
- Make sure the water line on the gage is stable, and allow any minor waves or turbulence to subside before making a gage reading, if conditions (i.e., high flows) are such that the water line continues to fluctuate, make the reading at the visually estimated average or middle of the fluctuation;
- Due to its location on the boulder at gage heights of approximately 3.70 feet (282 cfs), turbulence caused by water rushing over and around the boulder can yield inaccurate gage height readings. Under this circumstance, gage height readings should be made on the inclined staff gage located nearby (see Figure 3).

Gage height readings made on the manual staff gages can be converted to flow (cfs) by using the stage-discharge rating table shown in Table 6. A galvanized nail, painted fluorescent orange, is used to mark the gage height on the low flow vertical staff gage that corresponds to the minimum flow level.

6.2 Data Logger Download Procedures

The CR510 datalogger has the ability to store approximately 62,000 data points, which would represent approximately 3 months of data storage capacity under the current system configuration (measurements every 15 minutes). However, it is recommended that routine data downloads be made at least every 4-6 weeks. A copy of the operator's manual for the datalogger has been provided to the volunteer coordinator (Marc Hoechstetter). Field training events were held on-site with individuals, who volunteered to download the datalogger. Written instructions for datalogger download are provided below as well.

To complete a data download the following equipment is required:

- A portable computer capable of running a 32-bit operating system (e.g., Windows 95, 98, ME, NT, 2000, or XP). In addition, TCP/IP services (a standard computer networking protocol) must be running on the computer. If you are capable of accessing the Internet using your computer, then some form of TCP/IP services is already installed. However, in some instances, such as when using a portable computer that is never connected to a network, TCP/IP may not be present. If needed, specific instructions for configuring TCP/IP services are shown in Appendix C of this report.

- The PC200W and SCWIN software provided with the CR510 data logger must be installed on the portable computer as well. This software is also available for download at http://www.campbellsci.com/software.html.

- The RS-232 interface module and associated cabling. This small module allows communication between the datalogger and computer. The cable used to connect the computer to the module uses a 9-pin connection. Newer computers may only come with a USB port and not a 9-pin port. In this case a small adapter may need to be acquired from a computer store.

A set-up of the portable computer, PC200W software, and CR510 datalogger is required the first time the system is used. Subsequent downloads will not require this step, provided the same portable computer is used. The following outlines this procedure.

- When PC200W is first started, the Station Setup window appears. The Current Datalogger Profile, Logger Clock, and Program features of PC200W are integrated into this window. You can monitor input locations, collect and view data, or create a simple report by selecting the associated button on the toolbar to display a new window. To return to this main window from any other window, select the Station Setup button.

- The first thing you will need to do is establish communication between your computer and your Campbell Scientific datalogger.

- Connect your computer to the datalogger using a serial cable and SC32B interface device.

- From the Current Datalogger Profile portion of the window, press the Add button. A new window appears with a list of the dataloggers supported by PC200W. Choose the CR510 datalogger model from this list by highlighting it with the mouse pointer and pressing OK.

- A picture of the selected datalogger will appear at the bottom of the window. The default name for the datalogger can be used, or you can type a unique name in the yellow highlighted field.

- Choose the COM port on your computer that will be used to communicate with the datalogger. Only those COM ports that are configured on your computer and recognized by

Windows will be displayed. Most computers use COM1 as the default communications port. If you experience communication problems, check your computer's COM port setup to make sure it matches the COM port selected in PC200W.

- Ignore the security code settings field.

- The Logger Clock portion of the window displays the current time and date of your datalogger and the current time and date of your computer. If necessary, you can synchronize the datalogger clock with the computer clock by pressing Set Now. The datalogger clock can be offset from the computer clock in one hour increments, up to plus or minus 24 hours. Use the up arrow or down arrow to select an offset (or type in a new value over the old), then press Set Now to implement the change.

- The next step is to press the Connect button. This will establish a communication link between your computer and datalogger. When communication is established, the Connect button will change to Disconnect.

You are now ready to use PC200W's other features to collect and analyze data. The following outlines the procedure for downloading the datalogger.

- From the Data Collection window you can choose what data to collect and where to store the retrieved data. The window has the following components.

- Pressing the Collect button initiates the retrieval of stored data from the datalogger. You can stop the data collection process at any time by pressing Abort. The Progress indicator provides a visual cue that data is being collected successfully.

- When data is being collected from the datalogger, a sample of the data will appear in the Data Preview window. You can clear the data displayed in this window by pressing the Clear Screen button. This window has a 32K buffer; therefore, when collecting a large data file only the last 32K of the file will be displayed.

- There are two options for data collection. Choosing New Data From Logger collects only the data stored since the last data collection and appends this new data to the end of the existing file on your computer (if you choose the default filename). Choosing All Data From Logger collects all of the data in the datalogger and overwrites (i.e., replaces) the existing file on your computer (if you choose the default filename).

- The From/Collect To fields are used to select what data to collect from the datalogger and what file name to store the collected data under.

- Table-based dataloggers store their data in multiple tables within the datalogger memory. You will see a list of the tables that are available for collection. Simply highlight the name of the table that you want to collect.

- The Collect To field is used to specify the directory and filename for the collected file. The first time data is collected from a datalogger, a file box will appear with a default file name displayed. You can use this file name or type in a new one. You can change the file name at any time by selecting the file folder icon to the right of the Collect To field and typing in a new name.

Also, as part of this project an MS Access database was developed, and can be used to store the gage heights readings collected by volunteers. The database will also automatically convert the gage heights to streamflow using the stage-discharge relationship. The database has the ability to generate a standard report for dissemination to interested parties. This report is structured to calculate the median, maximum, minimum, and mean streamflow values for time periods specified by the user, as well as flag any violations of the prescribed minimum flow.

The database needs to run in MS Access 2000 or greater, and has been distributed on the CD containing this report. Specific procedures for operating the database are contained within the application. Features allow data (gage heights) to be imported in a variety of formats (e.g., Excel, text) and data can be output (gage height and corresponding streamflow) in similar formats as well.

7 Recommendations

The following recommendations to assist river users in continued monitoring of streamflow on the Deerfield River were developed.

- It is recommended that the Deerfield River near West Deerfield, MA (Gage No. 01170000) USGS gage be used to monitor flows from the Station No. 2 project. This gage can be used to give a close approximation of the timing and magnitude of flow releases from Station No. 2. It was agreed that in lieu of installing a second manual staff gage at Bardwell Ferry, the resources allocated for this item were used to facilitate continuous streamflow monitoring below the Fife Brook Hydroelectric Project. The main purpose of the proposed Bardwell Ferry manual staff gage was to monitor flow releases from the Station No. 2 project, as the stream reach below the project is a high quality coldwater fishery. Bardwell Ferry and the Deerfield River near West Deerfield, MA (Gage No. 01170000) [http://waterdata.usgs.gov/ma/nwis/rt] USGS gage are located approximately 2.5 miles and 4.4 miles below the Station No. 2 project, respectively.

  The drainage area at Station No. 2 is 505 square miles, while the drainage area at the USGS gage is 557 square miles. Thus, 52 square miles of unregulated drainage area contributes flow to this stream reach, in addition to the flow releases from Station No. 2.

  For a closer approximation of project flow releases, flow from the South River can be subtracted from the total flow measured at the Deerfield River near West Deerfield, MA USGS gage. Flow from the South River, which enters the Deerfield River 0.4 miles upstream of the West Deerfield USGS gage, is measured by the South River near Conway, MA (Gage No. 01169900) USGS gage (see Figure 1) [http://waterdata.usgs.gov/ma/nwis/sw]. The drainage area measured by the South River USGS gage is approximately 24 square miles; thus the flow resulting from subtracting South River flow from flow measured at the West Deerfield USGS gage would reflect 28 square miles of unregulated drainage area between the project and the West Deerfield USGS gage.

- It is recommended an annual survey of the gage reference marks, as well as the manual staff gage and water level sensor elevations be conducted so that any movement, settling, etc. can be noted and corrected. All reference marks and gage elevations are surveyed in at .001 feet accuracy. Streamflow measured at the Fife Brook Hydroelectric Project gage can become inaccurate if correct station survey levels are not maintained.

- It is recommended that streamflow measurements be conducted on an annual basis to either verify the accuracy of the stage-discharge rating curve or to follow changes (shifts) in the rating. Substantial sediment deposition or erosion near the area of a gage location can cause a shift in a stage-discharge rating curve. Shifts in the discharge rating reflect the fact that stage-discharge rating curves are not always permanent but vary from time to time, either gradually or abruptly. According to the USGS, if a streamflow measurement is within 5 percent of the streamflow discharge value indicated by the stage-discharge rating curve, the measurement is considered to verify the rating curve. However, if several consecutive measurements meet the 5-percent criterion, but they all plot on the same side of the defined segment of the stage-discharge rating curve, they may be considered to define a period of shifting control.

8 References

United States Geological Survey (USGS), Rantz S. E. and others, Measurement and Computation of Streamflow, Volumes 1 and 2, Water Supply Paper 2175, 1982.

Figure 1: Deerfield River Watershed within Massachusetts

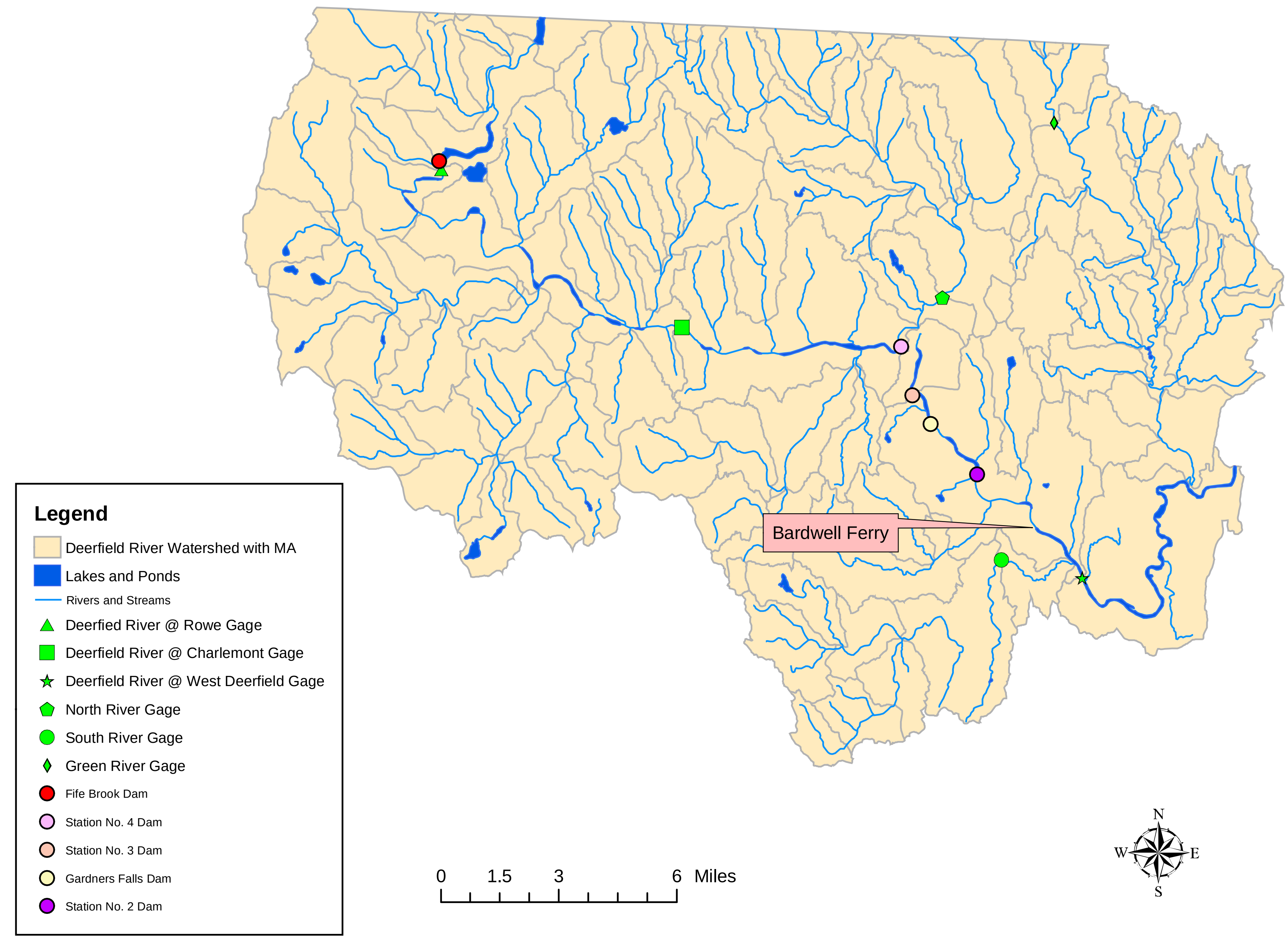


Figure 2: Low Flow Vertical Staff Gage

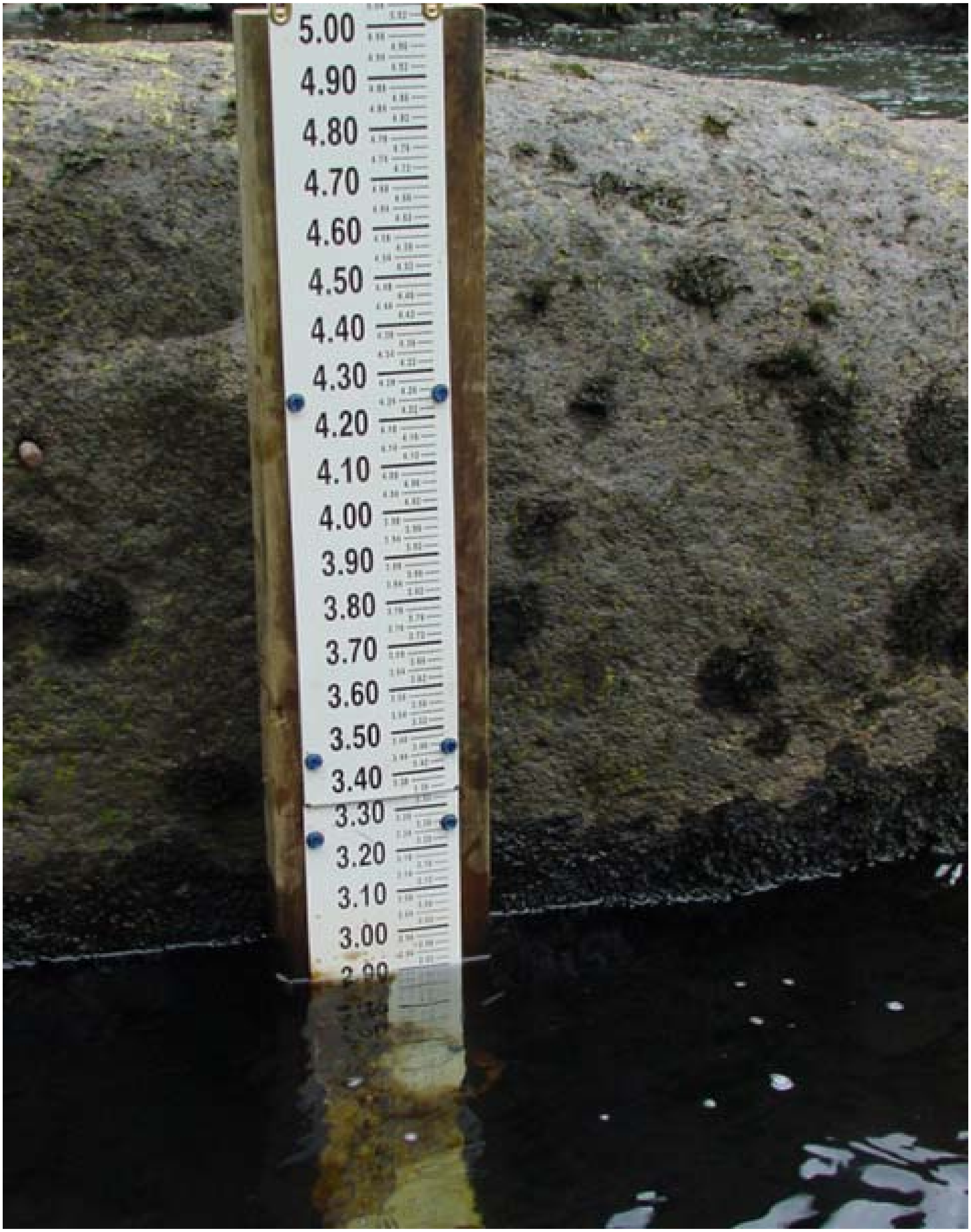


Figure 3: Inclined Slope Gage

Figure 4: Extreme High Flow Vertical Staff Gage

Figure 5: Overview of Gaging Station Setup

Figure 6: Upstream Calibration Flow Measurement Location

Figure 7: Downstream Calibration Flow Measurement Location

Figure 8: Stage-Discharge Rating Curve

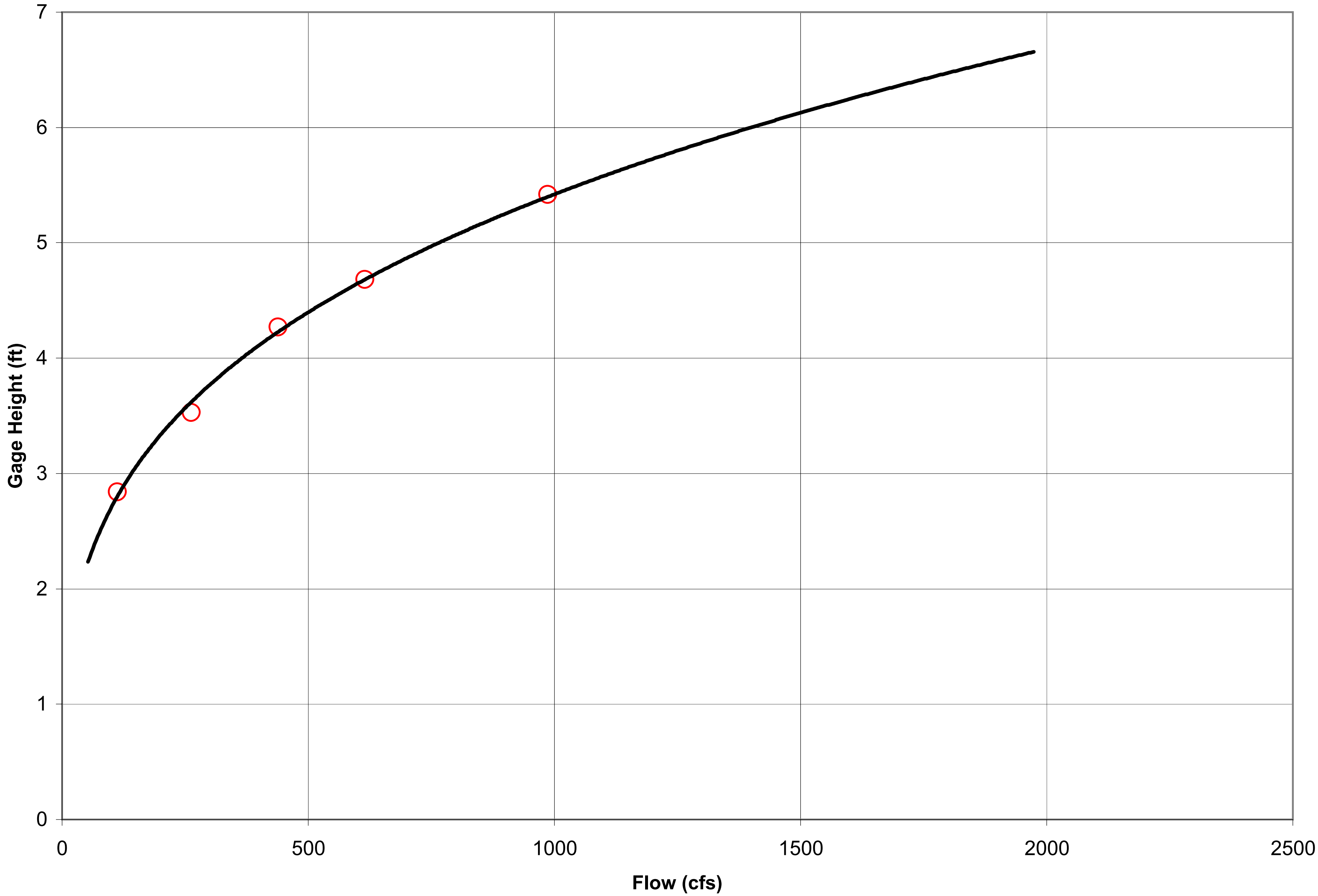
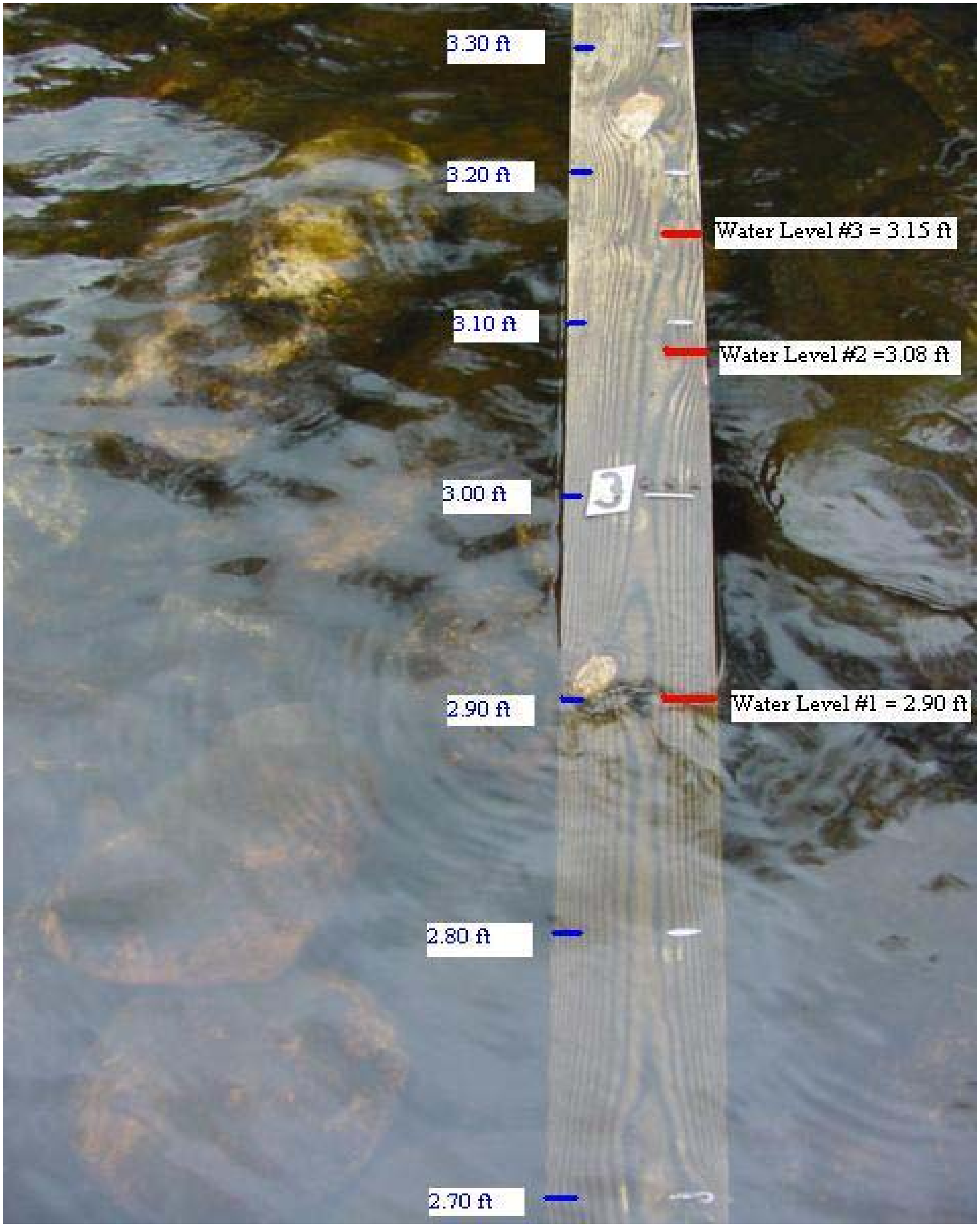


Figure 9: Water Level Sensor and Data Logger Located Inside USGS Gage House

Figure 10: Example Inclined Staff Gage Reading



Appendix A-Data from Stage-Discharge Rating Curve Calibration Measurements

Fife Brook Dam

Staff Gage (ft): **2.84**
Measured Flow = **113**
Date: **07/30/03**

Station	Width	Depth	Avg. Depth	Vel. @.60	Vel. @.20	Vel. @.80	Avg. Vel.	Cell Vel.	Flow
7.0		0.00		0.000	0.000	0.000	0.000		
	1.0		0.10					0.060	0.01
8.0		0.20		0.120	0.000	0.000	0.120		
	2.0		0.45					0.330	0.30
10.0		0.70		0.540	0.000	0.000	0.540		
	2.0		0.70					1.070	1.50
12.0		0.70		1.600	0.000	0.000	1.600		
	2.0		0.65					1.300	1.69
14.0		0.60		1.000	0.000	0.000	1.000		
	2.0		0.85					1.400	2.38
16.0		1.10		1.800	0.000	0.000	1.800		
	2.0		1.15					1.890	4.35
18.0		1.20		1.980	0.000	0.000	1.980		
	2.0		1.35					1.980	5.35
20.0		1.50		1.980	0.000	0.000	1.980		
	2.0		1.55					2.005	6.22
22.0		1.60		2.030	0.000	0.000	2.030		
	1.0		1.58					2.025	3.19
23.0		1.55		2.020	0.000	0.000	2.020		
	1.0		1.58					1.905	3.00
24.0		1.60		1.790	0.000	0.000	1.790		
	1.0		1.50					1.970	2.96
25.0		1.40		2.150	0.000	0.000	2.150		
	1.0		1.40					1.990	2.79
26.0		1.40		1.830	0.000	0.000	1.830		
	1.0		1.45					2.015	2.92
27.0		1.50		2.200	0.000	0.000	2.200		
	1.0		1.45					2.095	3.04
28.0		1.40		1.990	0.000	0.000	1.990		
	1.0		1.55					2.060	3.19
29.0		1.70		2.130	0.000	0.000	2.130		
	1.0		1.65					2.220	3.66
30.0		1.60		2.310	0.000	0.000	2.310		
	1.0		1.45					2.080	3.02
31.0		1.30		1.850	0.000	0.000	1.850		
	1.0		1.33					2.020	2.68
32.0		1.35		2.190	0.000	0.000	2.190		
	2.0		1.33					2.120	5.62
34.0		1.30		2.050	0.000	0.000	2.050		
	2.0		1.28					2.065	5.27
36.0		1.25		2.080	0.000	0.000	2.080		
	2.0		1.33					1.940	5.14
38.0		1.40		1.800	0.000	0.000	1.800		
	2.0		1.35					1.870	5.05
40.0		1.30		1.940	0.000	0.000	1.940		
	2.0		1.25					1.840	4.60
42.0		1.20		1.740	0.000	0.000	1.740		
	2.0		1.15					1.505	3.46
44.0		1.10		1.270	0.000	0.000	1.270		
	2.0		1.10					1.440	3.17
46.0		1.10		1.610	0.000	0.000	1.610		
	2.0		1.10					1.785	3.93
48.0		1.10		1.960	0.000	0.000	1.960		
	2.0		1.05					1.740	3.65
50.0		1.00		1.520	0.000	0.000	1.520		
	2.0		1.00					1.735	3.47
52.0		1.00		1.950	0.000	0.000	1.950		
	2.0		0.85					2.010	3.42
54.0		0.70		2.070	0.000	0.000	2.070		
	2.0		0.85					1.790	3.04
56.0		1.00		1.510	0.000	0.000	1.510		
	2.0		1.00					1.500	3.00
58.0		1.00		1.490	0.000	0.000	1.490		
	3.0		0.90					1.385	3.74
61.0		0.80		1.280	0.000	0.000	1.280		
	3.0		0.70					1.015	2.13
64.0		0.60		0.750	0.000	0.000	0.750		
	3.0		0.60					0.755	1.36
67.0		0.60		0.760	0.000	0.000	0.760		
	3.0		0.50					0.465	0.70
70.0		0.40		0.170	0.000	0.000	0.170		
	3.0		0.20					0.085	0.05
73.0		0.00		0.000	0.000	0.000	0.000		

Fife Brook Dam

Staff Gage (ft): **3.53**
Measured Flow = **262**
Date: **11/19/03**

Station	Width	Depth	Avg. Depth	Vel. @.60	Vel. @.20	Vel. @.80	Avg. Vel.	Cell Vel.	Flow
84.0		0.00		0.000	0.000	0.000	0.000		
	3.0		0.33					0.160	0.16
81.0		0.65		0.320	0.000	0.000	0.320		
	3.0		0.98					0.605	1.77
78.0		1.30		0.890	0.000	0.000	0.890		
	3.0		1.35					1.160	4.70
75.0		1.40		1.430	0.000	0.000	1.430		
	3.0		1.45					1.640	7.13
72.0		1.50		1.850	0.000	0.000	1.850		
	3.0		1.50					1.990	8.96
69.0		1.50		2.130	0.000	0.000	2.130		
	3.0		1.75					2.100	11.03
66.0		2.00		2.070	0.000	0.000	2.070		
	2.0		2.05					2.155	8.84
64.0		2.10		2.240	0.000	0.000	2.240		
	2.0		2.00					2.270	9.08
62.0		1.90		2.300	0.000	0.000	2.300		
	2.0		1.95					2.390	9.32
60.0		2.00		2.480	0.000	0.000	2.480		
	2.0		2.05					2.440	10.00
58.0		2.10		2.400	0.000	0.000	2.400		
	2.0		2.15					2.315	9.95
56.0		2.20		2.230	0.000	0.000	2.230		
	2.0		2.15					2.220	9.55
54.0		2.10		2.210	0.000	0.000	2.210		
	2.0		2.00					2.310	9.24
52.0		1.90		2.410	0.000	0.000	2.410		
	2.0		1.95					2.455	9.57
50.0		2.00		2.500	0.000	0.000	2.500		
	2.0		2.00					2.360	9.44
48.0		2.00		2.220	0.000	0.000	2.220		
	2.0		1.98					2.400	9.48
46.0		1.95		2.580	0.000	0.000	2.580		
	2.0		2.15					2.415	10.38
44.0		2.35		2.250	0.000	0.000	2.250		
	2.0		2.23					2.340	10.41
42.0		2.10		2.430	0.000	0.000	2.430		
	2.0		2.25					2.355	10.60
40.0		2.40		2.280	0.000	0.000	2.280		
	2.0		2.45					2.450	12.01
38.0		2.50		2.620	0.000	0.000	2.620		
	2.0		2.50					2.435	12.18
36.0		2.50		2.250	0.000	0.000	2.250		
	2.0		2.45					2.370	11.61
34.0		2.40		2.490	0.000	0.000	2.490		
	2.0		2.35					2.610	12.27
32.0		2.30		2.730	0.000	0.000	2.730		
	2.0		2.30					2.630	12.10
30.0		2.30		2.530	0.000	0.000	2.530		
	2.0		2.15					2.490	10.71
28.0		2.00		2.450	0.000	0.000	2.450		
	2.0		2.13					2.310	9.82
26.0		2.25		2.170	0.000	0.000	2.170		
	2.0		2.08					1.980	8.22
24.0		1.90		1.790	0.000	0.000	1.790		
	2.0		1.70					1.710	5.81
22.0		1.50		1.630	0.000	0.000	1.630		
	2.0		1.35					1.640	4.43
20.0		1.20		1.650	0.000	0.000	1.650		
	2.0		1.10					1.285	2.83
18.0		1.00		0.920	0.000	0.000	0.920		
	2.0		0.78					0.540	0.84
16.0		0.55		0.160	0.000	0.000	0.160		
	3.0		0.28					0.080	0.07
13.0		0.00		0.000	0.000	0.000	0.000		

Fife Brook Dam

Staff Gage (ft): **4.27**
Measured Flow = **439**
Date: **11/19/03**

Station	Width	Depth	Avg. Depth	Vel. @.60	Vel. @.20	Vel. @.80	Avg. Vel.	Cell Vel.	Flow
10.0		0.00		0.000	0.000	0.000	0.000		
	2.0		0.30					0.035	0.02
12.0		0.60		0.070	0.000	0.000	0.070		
	2.0		0.80					0.500	0.80
14.0		1.00		0.930	0.000	0.000	0.930		
	2.0		1.13					1.135	2.55
16.0		1.25		1.340	0.000	0.000	1.340		
	2.0		1.45					1.705	4.94
18.0		1.65		2.070	0.000	0.000	2.070		
	2.0		1.73					2.055	7.09
20.0		1.80		2.040	0.000	0.000	2.040		
	2.0		1.88					2.390	8.96
22.0		1.95		2.740	0.000	0.000	2.740		
	2.0		2.18					2.550	11.09
24.0		2.40		2.360	0.000	0.000	2.360		
	2.0		2.55					2.548	12.99
26.0		2.70		0.000	3.210	2.260	2.735		
	2.0		2.80					2.455	13.75
28.0		2.90		0.000	1.140	3.210	2.175		
	2.0		2.90					2.590	15.02
30.0		2.90		0.000	3.260	2.750	3.005		
	2.0		2.90					2.910	16.88
32.0		2.90		0.000	2.420	3.210	2.815		
	2.0		3.00					2.818	16.91
34.0		3.10		0.000	3.370	2.270	2.820		
	2.0		3.10					2.775	17.21
36.0		3.10		0.000	2.360	3.100	2.730		
	2.0		3.05					2.810	17.14
38.0		3.00		0.000	3.260	2.520	2.890		
	2.0		3.03					2.970	17.97
40.0		3.05		0.000	2.690	3.410	3.050		
	2.0		3.08					2.830	17.40
42.0		3.10		0.000	3.040	2.180	2.610		
	2.0		3.05					2.443	14.90
44.0		3.00		0.000	1.500	3.050	2.275		
	2.0		2.85					2.575	14.68
46.0		2.70		0.000	3.070	2.680	2.875		
	2.0		2.60					2.703	14.05
48.0		2.50		2.530	0.000	0.000	2.530		
	2.0		2.60					2.740	14.25
50.0		2.70		0.000	2.560	3.340	2.950		
	2.0		2.60					2.950	15.34
52.0		2.50		2.950	0.000	0.000	2.950		
	2.0		2.65					2.888	15.30
54.0		2.80		0.000	2.410	3.240	2.825		
	2.0		2.80					2.763	15.47
56.0		2.80		0.000	2.890	2.510	2.700		
	2.0		2.65					2.730	14.47
58.0		2.50		2.760	0.000	0.000	2.760		
	2.0		2.65					2.798	14.83
60.0		2.80		0.000	2.330	3.340	2.835		
	2.0		2.80					2.835	15.88
62.0		2.80		0.000	3.090	2.580	2.835		
	2.0		2.75					2.885	15.87
64.0		2.70		0.000	2.290	3.580	2.935		
	2.0		2.70					2.863	15.46
66.0		2.70		0.000	3.290	2.290	2.790		
	2.0		2.60					2.905	15.11
68.0		2.50		3.020	0.000	0.000	3.020		
	2.0		2.40					3.050	14.64
70.0		2.30		3.080	0.000	0.000	3.080		
	3.0		2.20					2.775	18.32
73.0		2.10		2.470	0.000	0.000	2.470		
	3.0		2.10					2.315	14.58
76.0		2.10		2.160	0.000	0.000	2.160		
	3.0		1.83					1.755	9.61
79.0		1.55		1.350	0.000	0.000	1.350		
	3.0		1.33					1.060	4.21
82.0		1.10		0.770	0.000	0.000	0.770		
	6.0		0.55					0.385	1.27
88.0		0.00		0.000	0.000	0.000	0.000		

Fife Brook Dam

Staff Gage (ft): **4.68**
Measured Flow = **615**
Date: **11/19/03**

Station	Width	Depth	Avg. Depth	Vel. @.60	Vel. @.20	Vel. @.80	Avg. Vel.	Cell Vel.	Flow
91.5		0.00		0.000	0.000	0.000	0.000		
	3.5		0.20					0.020	0.01
88.0		0.40		0.040	0.000	0.000	0.040		
	3.0		0.63					0.365	0.68
85.0		0.85		0.690	0.000	0.000	0.690		
	3.0		1.18					0.955	3.37
82.0		1.50		1.220	0.000	0.000	1.220		
	3.0		1.75					1.550	8.14
79.0		2.00		1.880	0.000	0.000	1.880		
	3.0		2.25					2.345	15.83
76.0		2.50		2.810	0.000	0.000	2.810		
	2.0		2.45					2.825	13.84
74.0		2.40		2.840	0.000	0.000	2.840		
	2.0		2.60					2.873	14.94
72.0		2.80		0.000	2.640	3.170	2.905		
	2.0		2.75					2.813	15.47
70.0		2.70		0.000	2.980	2.460	2.720		
	2.0		2.80					2.808	15.72
68.0		2.90		0.000	2.110	3.680	2.895		
	2.0		2.95					3.080	18.17
66.0		3.00		0.000	4.130	2.400	3.265		
	2.0		3.10					3.200	19.84
64.0		3.20		0.000	2.460	3.810	3.135		
	2.0		3.00					3.148	18.89
62.0		2.80		0.000	3.820	2.500	3.160		
	2.0		2.90					3.358	19.47
60.0		3.00		0.000	3.070	4.040	3.555		
	2.0		3.10					3.388	21.00
58.0		3.20		0.000	3.820	2.620	3.220		
	2.0		3.25					3.155	20.51
56.0		3.30		0.000	2.620	3.560	3.090		
	2.0		3.25					3.108	20.20
54.0		3.20		0.000	3.670	2.580	3.125		
	2.0		3.15					3.248	20.46
52.0		3.10		0.000	3.260	3.480	3.370		
	2.0		3.10					3.333	20.66
50.0		3.10		0.000	3.560	3.030	3.295		
	2.0		3.15					3.273	20.62
48.0		3.20		0.000	2.820	3.680	3.250		
	2.0		3.20					3.245	20.77
46.0		3.20		0.000	3.480	3.000	3.240		
	2.0		3.40					3.075	20.91
44.0		3.60		0.000	2.330	3.490	2.910		
	2.0		3.60					2.968	21.37
42.0		3.60		0.000	3.430	2.620	3.025		
	2.0		3.60					3.243	23.35
40.0		3.60		0.000	3.020	3.900	3.460		
	2.0		3.60					3.398	24.46
38.0		3.60		0.000	3.950	2.720	3.335		
	3.0		3.60					3.150	34.02
35.0		3.60		0.000	2.390	3.540	2.965		
	5.0		3.60					3.198	57.56
30.0		3.60		0.000	3.880	2.980	3.430		
	2.0		3.20					3.453	22.10
28.0		2.80		0.000	3.330	3.620	3.475		
	2.0		3.10					3.295	20.43
26.0		3.40		0.000	3.880	2.350	3.115		
	2.0		3.20					2.948	18.86
24.0		3.00		0.000	2.470	3.090	2.780		
	2.0		2.85					2.725	15.53
22.0		2.70		0.000	3.090	2.250	2.670		
	3.0		2.35					2.640	18.61
19.0		2.00		2.610	0.000	0.000	2.610		
	3.0		2.05					2.555	15.71
16.0		2.10		2.500	0.000	0.000	2.500		
	3.0		1.30					2.525	9.85
13.0		0.50		2.550	0.000	0.000	2.550		
	3.0		0.68					1.650	3.34
10.0		0.85		0.750	0.000	0.000	0.750		
	4.0		0.43					0.375	0.64
6.0		0.00		0.000	0.000	0.000	0.000		

Fife Brook Dam

Staff Gage (ft): **5.42**
Measured Flow = **987**
Date: **11/19/03**

Station	Width	Depth	Avg. Depth	Vel. @.60	Vel. @.20	Vel. @.80	Avg. Vel.	Cell Vel.	Flow
0.0		0.00		0.000	0.000	0.000	0.000		
	4.0		1.00					0.710	2.84
4.0		2.00		1.420	0.000	0.000	1.420		
	4.0		2.00					1.425	11.40
8.0		2.00		1.430	0.000	0.000	1.430		
	4.0		2.25					1.815	16.34
12.0		2.50		2.200	0.000	0.000	2.200		
	4.0		2.48					2.655	26.28
16.0		2.45		3.110	0.000	0.000	3.110		
	4.0		2.43					3.420	33.17
20.0		2.40		3.730	0.000	0.000	3.730		
	4.0		2.45					2.300	22.54
24.0		2.50		0.870	0.000	0.000	0.870		
	4.0		2.50					2.095	20.95
28.0		2.50		3.320	0.000	0.000	3.320		
	4.0		2.35					3.270	30.74
32.0		2.20		3.220	0.000	0.000	3.220		
	4.0		2.25					3.445	31.01
36.0		2.30		3.670	0.000	0.000	3.670		
	4.0		2.35					3.470	32.62
40.0		2.40		3.270	0.000	0.000	3.270		
	4.0		2.40					3.125	30.00
44.0		2.40		2.980	0.000	0.000	2.980		
	4.0		2.40					3.070	29.47
48.0		2.40		3.160	0.000	0.000	3.160		
	4.0		2.45					2.830	27.73
52.0		2.50		2.500	0.000	0.000	2.500		
	4.0		2.25					2.860	25.74
56.0		2.00		3.220	0.000	0.000	3.220		
	4.0		2.20					3.275	28.82
60.0		2.40		3.330	0.000	0.000	3.330		
	4.0		2.65					2.820	29.89
64.0		2.90		0.000	1.270	3.350	2.310		
	4.0		2.70					2.415	26.08
68.0		2.50		2.520	0.000	0.000	2.520		
	4.0		2.45					3.010	29.50
72.0		2.40		3.500	0.000	0.000	3.500		
	4.0		2.35					3.350	31.49
76.0		2.30		3.200	0.000	0.000	3.200		
	4.0		2.40					3.350	32.16
80.0		2.50		3.500	0.000	0.000	3.500		
	4.0		2.50					3.325	33.25
84.0		2.50		3.150	0.000	0.000	3.150		
	4.0		2.60					3.438	35.75
88.0		2.70		0.000	2.920	4.530	3.725		
	4.0		2.60					3.748	38.97
92.0		2.50		3.770	0.000	0.000	3.770		
	4.0		2.70					3.530	38.12
96.0		2.90		0.000	2.480	4.100	3.290		
	4.0		2.80					3.525	39.48
100.0		2.70		0.000	4.460	3.060	3.760		
	4.0		2.65					3.298	34.95
104.0		2.60		0.000	1.550	4.120	2.835		
	4.0		2.35					3.108	29.21
108.0		2.10		3.380	0.000	0.000	3.380		
	4.0		2.20					3.495	30.76
112.0		2.30		3.610	0.000	0.000	3.610		
	4.0		2.40					3.325	31.92
116.0		2.50		3.040	0.000	0.000	3.040		
	4.0		2.45					3.335	32.68
120.0		2.40		3.630	0.000	0.000	3.630		
	4.0		2.35					3.640	34.22
124.0		2.30		3.650	0.000	0.000	3.650		
	4.0		2.45					3.450	33.81
128.0		2.60		0.000	2.570	3.930	3.250		
	4.0		2.40					2.865	27.50
132.0		2.20		2.480	0.000	0.000	2.480		
	4.0		2.15					2.070	17.80
136.0		2.10		1.660	0.000	0.000	1.660		
	4.0		2.10					1.005	8.44
140.0		2.10		0.350	0.000	0.000	0.350		
	5.0		1.05					0.175	0.92
145.0		0.00		0.000	0.000	0.000	0.000		

Appendix B-General Specifications for Water Level Sensor and Data Logger

Accubar Bubble Gauge 5600-0131-3, -4

The Accubar Bubble Gauge is a self-contained, mercury-free and nitrogen-free complete bubbler apparatus designed for low maintenance water level measuring.

The Accubar Bubble Gauge tracks rapid level changes by purging the orifice line prior to each measurement which eliminates the time lag produced by constant bubble rate systems when water levels rise rapidly.

Using the Sutron Accubar® Gauge Pressure Sensor as the controlling and sensing element, the Accubar Bubbler is an **exceptionally stable and highly accurate** water level measuring device.

- **Low Maintenance Water Level Monitoring**
- **Satellite Telemetry**
- **SDI-12**
- **Temperature & Pressure in One Measurement**
- **New Commands**
- **Supports Averaging**
- **Measures in tenths of a second**
- **Additional Operating Modes**
- **Outperforms Constant Bubble System**
- **Gives Real-Time Readings Right Now - not in 15 minutes**
- **Quickest Response to Change in Water Levels**

WIRELESS REMOTE OPTION NOW AVAILABLE

Specifications

Specifications subject to change without notice

ELECTRICAL	
Power Required	8-16VDC
Control Interface	SDI-12
Outputs	SDI-12, Quadrature (-3 only), Analog (-4 only)
Quiescent Current	<1 mA (-3 & -5) 8 mA (-4)
PNEUMATIC	
Pressure Range	0-22 psi
Accuracy	0-10 ft. 0.02% FSO 10-50 ft. 0.1% of reading
Resolution	0.0001 psi
Purge Pressure	35 psi max.
Bubble Rate	Purges before each reading (no continuous bubble)
Compressor Type	Piston and cylinder compressor
MECHANICAL	
Enclosure	NEMA-4 fiberglass
Dimensions	12 in. x 15 in. x 7.5 in.
Connections	9 position terminal block
Pressure Outlet	3/8 in. O.D. tubing
ENVIRONMENTAL	
Temperature	-40°C to +60°C

Applications

- Stream Gauging Station
- Lake Level Monitoring Station
- Portable Flood Warning Station
- Wastewater Lift Station Monitoring
- Ground Water Monitoring

Ordering Information

Part Number	*Description*
5600-0131-3	Accubar Bubble Gauge with SDI-12 and quadrature outputs
5600-0131-4	Accubar Bubble Gauge with SDI-12 and analog outputs
Accessories	***Description***
2911-1183	Tubing, Orifice Line Black Polyurethane **up to 2000 feet (609.6 meters)**
2911-1184	Replacement Desiccant, full canister
7191-1003	Refill Desiccant for 2911-1184

CR510 Specifications

Electrical specifications are valid over a -25° to +50°C range unless otherwise specified; non-condensing environment required. To maintain electrical specifications, Campbell Scientific recommends recalibrating dataloggers every two years.

PROGRAM EXECUTION RATE

System tasks initiated in sync with real-time up to 64 Hz. One measurement with data transfer is possible at this rate without interruption.

ANALOG INPUTS

NUMBER OF CHANNELS: 2 differential or 4 single-ended, individually configured.

RANGE AND RESOLUTION:

Full Scale Input Range (mV)	*Resolution (µV) Differential*	*Single-Ended*
±2500	333	666
±250	33.3	66.6
±25	3.33	6.66
±7.5	1.00	2.00
±2.5	0.33	0.66

INPUT SAMPLE RATES: Includes the measurement time and conversion to engineering units. The fast and slow measurements integrate the signal for 0.25 and 2.72 ms, respectively. Differential measurements incorporate two integrations with reversed input polarities to reduce thermal offset and common mode errors.

Fast differential voltage:	4.2 ms
Slow differential voltage:	9.2 ms
Differential with 60 Hz rejection:	25.9 ms

ACCURACY: ±0.1% of FSR (-25° to 50°C); ±0.05% of FSR (0° to 40°C); e.g., ±0.1% FSR = ±5.0 mV for ±2500 mV range

INPUT NOISE VOLTAGE (for ±2.5 mV range):
Fast differential: 0.82 µV rms
Slow differential: 0.25 µV rms
Differential with
60 Hz rejection: 0.18 µV rms

COMMON MODE RANGE: ±2.5 V

DC COMMON MODE REJECTION: > 140 dB

NORMAL MODE REJECTION: 70 dB (60 Hz with slow differential measurement)

INPUT CURRENT: ±9 nA maximum

INPUT RESISTANCE: 20 Gohms typical

ANALOG OUTPUTS

DESCRIPTION: 2 switched excitations, active only during measurement, one at a time.

RANGE: ±2.5 V

RESOLUTION: 0.67 mV

ACCURACY: ±2.5 mV (0° to 40°C); ±5 mV (-25° to 50°C)

CURRENT SOURCING: 25 mA

CURRENT SINKING: 25 mA

FREQUENCY SWEEP FUNCTION: The switched outputs provide a programmable swept frequency, 0 to 2.5 V square wave for exciting vibrating wire transducers.

RESISTANCE MEASUREMENTS

MEASUREMENT TYPES: The CR510 provides ratiometric bridge measurements of 4- and 6-wire full bridge, and 2-, 3-, and 4-wire half bridges. Precise dual polarity excitation using any of the switched outputs eliminates dc errors. Conductivity measurements use a dual polarity 0.75 ms excitation to minimize polarization errors.

ACCURACY: ±0.02% of FSR plus bridge errors.

PERIOD AVERAGING MEASUREMENTS

DEFINITION: The average period for a single cycle is determined by measuring the duration of a specified number of cycles. Any of the 4 single-ended analog input channels can be used. Signal attenuation and ac coupling is typically required.

INPUT FREQUENCY RANGE:

Signal peak-to-peak[1] Min.	*Max.*	*Min. Pulse w.*	*Max Freq.[2]*
500 mV	5.0 V	2.5 µs	200 kHz
10 mV	2.0 V	10 µs	50 kHz
5 mV	2.0 V	62 µs	8 kHz
2 mV	2.0 V	100 µs	5 kHz

RESOLUTION: 35 ns divided by the number of cycles measured

ACCURACY: ±0.03% of reading

TIME REQUIRED FOR MEASUREMENT: Signal period multiplied by the number of cycles measured plus 1.5 cycles + 2 ms.

PULSE COUNTERS

NUMBER OF CHANNELS: 2 eight-bit or 1 sixteen-bit; software selectable as switch closure, high frequency pulse, or low-level ac modes. An additional channel (C2/P3) can be software configured to read switch closures at rates up to 40 Hz.

MAXIMUM COUNT RATE: 16 kHz, eight-bit counter; 400 kHz, sixteen-bit counter. Channels are scanned at 8 or 64 Hz (software selectable).

SWITCH CLOSURE MODE:
Minimum Switch Closed Time: 5 ms
Minimum Switch Open Time: 6 ms
Maximum Bounce Time: 1 ms open without being counted

HIGH FREQUENCY PULSE MODE:
Minimum Pulse Width: 1.2 µs
Maximum Input Frequency: 400 kHz
Maximum Input Voltage: ±20 V
Voltage Thresholds: Count upon transition from below 1.5 V to above 3.5 V at low frequencies. Larger input transitions are required at high frequencies because of input filter with 1.2 µs time constant. Signals up to 400 kHz will be counted if centered around +2.5 V with deviations ≥ ± 2.5 V for ≥ 1.2 µs.

LOW LEVEL AC MODE:
(Typical of magnetic pulse flow transducers or other low voltage, sine wave outputs.)

Input Hysteresis: 14 mV
Maximum ac Input Voltage: ±20 V
Minimum ac Input Voltage:

*(Sine wave mV rms)**	*Range (Hz)*
20	1 to 1000
200	0.5 to 10,000
1000	0.3 to 16,000

*16-bit config. or 64 Hz scan req'd for freq. > 2048 Hz

DIGITAL I/O PORTS

DESCRIPTION: Port C1 is software selectable as a binary input, control output, or as an SDI-12 port. Port C2/P3 is input only and can be software configured as an SDI-12 port, a binary input, or as a switch closure counter (40 Hz max).

OUTPUT VOLTAGES (no load): high 5.0 V ±0.1 V; low < 0.1 V

OUTPUT RESISTANCE: 500 ohms

INPUT STATE: high 3.0 to 5.5 V; low -0.5 to 0.8 V

INPUT RESISTANCE: 100 kohms

SDI-12 INTERFACE STANDARD

DESCRIPTION: Digital I/O Ports C1-C2 support SDI-12 asynchronous communication; up to ten SDI-12 sensors can be connected to each port. Meets SDI-12 standard Version 1.2 for datalogger and sensor modes.

EMI and ESD PROTECTION

The CR510 is encased in metal and incorporates EMI filtering on all inputs and outputs. Gas discharge tubes provide robust ESD protection on all terminal block inputs and outputs. The following European CE standards apply.

EMC tested and conforms to BS EN61326:1998.

Details of performance criteria applied are available upon request.

CPU AND INTERFACE

PROCESSOR: Hitachi 6303.

PROGRAM STORAGE: Up to 16 kbytes for active program; additional 16 kbytes for alternate programs. Operating system stored in 128 kbytes Flash memory.

DATA STORAGE: 128 kbytes SRAM standard (approximately 62,000 values). Additional 2 Mbytes Flash available as an option.

OPTIONAL KEYBOARD DISPLAY: 8 digit LCD (0.5" digits).

PERIPHERAL INTERFACE: 9 pin D-type connector for keyboard display, storage module, modem, printer, card storage module, and RS-232 adapter.

BAUD RATES: Selectable at 300, 1200, and 9600, 76,800 for certain synchronous devices. ASCII communication protocol is one start bit, one stop bit, eight data bits (no parity).

CLOCK ACCURACY: ±1 minute per month

SYSTEM POWER REQUIREMENTS

VOLTAGE: 9.6 to 16 Vdc

TYPICAL CURRENT DRAIN: 1.3 mA quiescent, 13 mA during processing, and 46 mA during analog measurement.

BATTERIES: Any 12 V battery can be connected as a primary power source. Several power supply options are available from Campbell Scientific. The model CR2430 lithium battery for clock and SRAM backup has a capacity of 270 mAhr.

PHYSICAL SPECIFICATIONS

SIZE: 8.4" x 1.5" x 3.9" (21.3 cm x 3.8 cm x 9.9 cm). Additional clearance required for serial cable and sensor leads.

WEIGHT: 15 oz. (425 g)

WARRANTY

Three years against defects in materials and workmanship.

We recommend that you confirm system configuration and critical specifications with Campbell Scientific before purchase.

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Appendix C-Specific Instructions for Configuring TCP/IP Services

Configuration of TCP/IP Services

Following are the procedures for enabling TCP/IP communication on a Windows 95, 98, or NT system. The setup for Windows 2000 or XP is similar; see the specific documentation or help for these systems to add a dial-up connection and associate it with TCP/IP.

Before beginning this procedure make sure that you have your Windows installation CD-ROM (or floppy disks as appropriate) handy. As you install these options you may be prompted to insert various disks or the CD-ROM to complete the installation.

1. Click on the Windows Start button and select Settings | Control Panel.
2. When the Control Panel window comes up, double click on the Add/Remove Programs icon.
3. Select the Windows Setup tab.
4. Select Communications and click on the Details button.
5. On the Communications options screen click the box by “Dial-Up Networking” (Win 98/95) or “Phone Dialer” (NT). If already checked, click Cancel and skip to step 9.
6. Click OK on the Communications Options screen and on the Windows Setup screen.
7. Provide the Windows installation software as prompted and then follow the directions.
8. When you are prompted to reboot the computer choose Yes.
9. After the computer boots, go to the Windows Control Panel and double click on the Network icon.
10. In the list box on the Configuration tab (Win95/98) or Protocols tab (NT) of the Network window which comes up, see if there is an entry TCP/IP -> Dial-Up Adapter or TCP/IP protocol. If this entry exists, click Cancel and skip the next steps.
11. Click on the Add button. In the Select Network Component Type window which comes up select Protocol or TCP/IP protocol and click on the Add or OK button.
12. When the Select Network Protocol window comes up, select Microsoft under Manufacturers:, and TCP/IP under Network Protocols: Click OK.